IS 12188 (1987): Electric direct-arc melting furnaces [ETD 17: Industrial Electroheating Equipment]

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Indian Standard

SPECIFICATION FOR ELECTRIC DIRECT ARC MELTING FURNACES

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Indian Standard

SPECIFICATION FOR ELECTRIC DIRECT ARC MELTING FURNACES

Industrial Electroheating Equipment Sectional Committee, ETDC 61

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0. FOREWORD

0.1 This Indian Standard was adopted by the Bureau of Indian Standards on 28 September 1987, after the draft finalized by the Electroheating Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard covers the service conditions and design features of three-phase direct arc melting furnaces for steel scrap of nominal capacities between 2 and 50 tonnes.

0.3 The general and safety requirements, and methods of tests are covered in the following standards. This standard shall, therefore, be read in conjunction with the following:

IS : 9080 (Part 1) - 1979 Safety requirements in electroheat installations : Part 1 General requirements

IS : 9080 (Part 4) - 1981 Safety requirements in electroheat installations: Part 4 Particular requirements for arc furnace installations

IS : 9021-1978 General test conditions for industrial electroheating equipment

Doc: ETDC 61 (2377) Methods of test for direct arc melting furnaces

IS : 4041-1961 Glossary of terms relating to refractory material

0.4 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard covers the service conditions and design features of three-phase direct arc melting furnaces of nominal capacities between 2 and 50 tonnes operating on 100 percent steel scrap (without direct reduced iron) and conventional fully refractory lined shell and roof (without water cooled panels for side wall roof).

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Arc Furnace — Furnace in which a three phase ac electric arc is the main source of heat.

2.2 Direct Arc Furnace — Arc furnace in which the electric arc is generated between the electrode and the charge.

2.3 Direct Arc Melting Furnace Installation — Furnace assembly with complete set of electrical equipment including furnace sub-station with furnace transformer reactor (where applicable), switchgear, automatic electrode regulator, furnace control instrument panel/desk, signalling devices, busbars, interconnecting cables, pneumatic, hydraulic and cooling water circuits, etc, but excluding the following:

a) Fume extraction equipment;
b) Ventilation equipment;
c) Power factor correction and reactive power compensation equipment;
d) Harmonic filters; and
e) Other auxiliary operation equipment, such as charging buckets, ladles, slag pots, cooling water circulating system, compressor plant and electrode make up platform.

2.4 Furnace Body — Refractory lined shell with refractory lined roof, and openings for operating slagging off, tapping and top charging.

2.5 Rated Volume of the Furnace — Total internal volume of the furnace body as defined by the inner surface of the specified shell lining (The volume between the upper level of the shell and the underside of the roof is not included in the rated volume).

2.6 Sill Level — The maximum level of the molten metal including slag which can be maintained within a refractory lined furnace shell, without overflowing of metal or slag through the slag door, the furnace being in vertical position.

2.7 Rated Capacity of Furnace — Calculated capacity in tonnes of liquid metal for which the furnace has been designed, built and marked. This capacity is defined with specified shell lining at 50 mm below sill level and considering the density of liquid metal as 7 kg/dm^3.

The volume between the sill level and the liquid metal level which is 50 mm below sill level is allowed for slag.

2.8 Minimum Bulk Weight of Scrap for the Single Complete Maximum Charge of the Furnace (t/m^3) — Ratio of the furnace rated capacity to its rated volume.

2.9 Furnace High Voltage Switch — High voltage switch which serves for switching *ON* and *OFF* the furnace transformer under load in accordance with operating requirements.

2.10 Furnace Transformer — The transformer feeding power to the arc furnace from the high voltage network and providing a voltage range suitable for the furnace operation.

2.11 Rated Power of Furnace Transformer — Maximum admissible continuous apparent power (in kVA) of furnace transformer (without time limitation) at the specified voltage tappings.

2.12 Melt-Down Power of Furnace Transformer — Maximum admissible apparent power (in kVA) as per the load cycle.

2.13 Load Cycle — Unless otherwise agreed between the manufacturer and the user, the furnace transformer should be suitable for the following load cycle:

a) 120 percent load for 2 hours,

b) 60 percent load for 1 hour, and

c) 0 percent load for 1/2 hour.

2.14 Reactor — Reactor used, if it is required, in the arc furnace installations with the object of ensuring the stability of the electric arc and limiting the short-circuit current during the operation.

2.15 Arc Furnace Electrode — Current carrying column, in general, made up of graphite section, intended to supply power to the charge material contained in the furnace body and to maintain the electric arc.

2.16 Electrode Clamp — A device for clamping the electrode in a given position under a recommended pressure for supply of current to the electrodes.

2.17 Heavy Current Line (Secondary Voltage) — Assembly of series connected elements of the secondary circuit comprising electrodes and secondary voltage busbar system (electrode clamp, busbar system of electrode arms, flexible cables and transformer secondary busbar connection) intended to carry the required electrical power from the transformer to the charge material contained in the furnace body.

2.18 Main Electrical Circuit of the Arc Furnace Installation — The part of the arc furnace installation, which includes the high voltage equipment (including reactor when used), furnace transformer, heavy current line, arc and charge.

2.19 Melt-Down Time — Melt-down time is a period elapsed from the moment of switching on after the first charging to the moment of complete melt down of the charge, with subtraction of the time lost for the switch off duration arising out of one additional back charge and emergency disconnection due to charge collapse or any other operational interruption.

NOTE — The end of melt-down period to be reckoned when no unmelted piece of scrap exists within the molten bath having a temperature of 1 520°C for mild steel when measured with a dip type thermocouple near the slag door. No consideration is given for the charge scrap hanging on the banks in unmelted stage.

2.20 Specific Energy Consumption for Melt-Down (kWh/t) — Quantity of electric energy measured in kWh consumed by an arc furnace installation at the primary side of the transformer, for the complete melting of one tonne of specified furnace charge.

NOTE 1 — For end of melt-down period *see* **2.19**.

NOTE 2 — The energy consumed by the furnace installation does not include power factor correction capacitors and other anxiliary/ancillary equipment including those given in **2.3**.

2.21 Specific Melt-down Rate (t/h) — Total quantity of scrap charge measured in tonnes, divided by nett melt-down time measured in hours.

2.22 Furnace Shell — The receptacle to be lined with refractory for melting of the charge material. This may be fixed shell, removable shell or split shell design.

2.23 Slag Door — Opening at the rear side of the furnace shell for taking out the slag, inclusion of additives, etc, located at 180° to spout opening.

2.24 Pouring Spout — Spout for tapping out molten metal.

2.25 Inspection/Side Door — Opening (if provided), in addition to the slag door, for inspection of furnace lining located at 90° to the spout on outerside.

2.26 Roof Ring — The circular ring on which the refractory roof is formed and placed on the furnace shell.

2.27 Furnace Roof — The top refractory lined cover of the furnace. This may be fixed, removable or slewing aside type.

2.28 Cradle Beam — The pedestal on which the furnace, along with its platform, rests under normal condition and guides the tilting position of the furnace during deslagging and pouring operations.

2.29 Electrode Arms — The arms holding the electrodes including the clamping arrangement and the copper bus tubes/busbars carrying the current to the electrodes.

2.30 Furnace Shell Diameter — The maximum inside shell diameter of an unlined furnace.

2.31 Depth of Shell — The maximum inside measurement between the bottom of an unlined furnace shell up to the top of the furnace shell (including bazel ring).

2.32 Bazel Ring — A stiffening ring fitted at the top of the furnace shell which provides seating/sealing between the roof and furnace shell. This may be water cooled.

2.33 Electrode Cooling Gland/Economizer — Water cooled annular ring fitted on top of the electrode port holes of the refractory lined roof or inserted in the electrode port holes of the refractory lined roof.

2.34 Flame Guards (When Provided) — Metallic heat shield fitted below the electrode clamp to protect the clamp from flames.

2.35 Pitch Circle Diameter — The diameter of the circle circumscribing the centres of the three electrodes.

2.36 Furnace Platform — A working platform for deslagging and other furnace operations. The platform is not to be considered as a part of furnace structurals.

2.37 Charge — The mixture of metallic scrap in the form of heavy melting scrap, medium melting scrap, bundles, turning, boring, shreaded scrap or any other type of metallic scrap.

The average bulk density of this mixture should be minimum 1 000 to 2 000 kg/m^3.

3. SERVICE CONDITIONS

3.1 The temperature, relative humidity and service conditions are as following:

a) Maximum ambient air temperature	—	50°C
b) Maximum daily average air temperature	—	40°C
c) Minimum temperature of cooling water	—	5°C
d) Maximum temperature of cooling water	—	35°C
e) Maximum average cooling water temperature	—	30°C
f) Relative humidity	—	95 percent *Max*

NOTE — Conditions at (a) and (f) not to occur simultaneously.

3.2 Quality of Cooling Water — The cooling water used for the arc furnace shall be as follows:

a) Total dissolved solids	—	150 ppm
b) Total hardness, *Max* (in terms of equivalent $CaCo_3$)	—	100 ppm
c) Carborate hardness, *Max*	—	50 ppm
d) *p*H value	—	7-8
e) Suspended particle	—	less than 100 ppm
f) Particle size, *Max*	—	0·1 mm

4. DESIGN FEATURES

4.1 Furnace Shell — The furnace should be so designed that furnace shell maintains vertical position, when free from any external force.

When the furnace is tilted forward, it should be possible to empty the furnace completely. The centre of gravity of furnace assembly should be so located that even at maximum tilted position, there is no danger of overshooting. When the furnace is tilted backward, it should be possible to remove all slag from a depth of 50 mm below the sill level.

4.2 Electrode Mast — All structural/fabricated work should be strong enough to take care of any mechanical abrasion during electrode movement and electromagnetic stresses developed during arc furnace operations.

4.3 Electrode Arm — All the current carrying parts of electrode arm should be properly insulated to withstand the highest secondary voltage of the transformer and electrical surges in the system. It should have provision for adjustment of position of electrodes with respect to pitch circle diameter of the port holes so that they match the holes in the roof of the furnace. The electrode arm assembly including the electrode clamp shall be designed for the maximum secondary current as given in Table 1.

4.4 Electrode Control — Should be so designed as to achieve most optimum arc power. The electrode control system should have adjustement for sensitivity, stability electrode raising and lowering speed.

4.5 Furnace Transformer — The transformer should be designed to withstand electromagnetic stress in arc furnace operation. Sufficient number of voltage tappings should be provided to regulate power input, arc length to suit process requirement. The transformer should be OFWF cooled for ratings 1·5 MVA and above, and generally conform to IS : 2026 wherever applicable till such a time relevant Indian Standard for arc furnace transformers is adopted. Till such time the impulse voltage withstand level and power frequency voltage withstand level of furnace transformer HT and LT winding shall be designed for one step higher insulating level than that specified in IS : 2026.

The typical recommended values for maximum/minimum voltage ratings, etc, may be as per Table 1 for guidance only.

List of accessories to be supplied with the furnace transformer, in addition to those specified in IS : 2026, is as follows:

a) Motor operated on load/off load tap changer;

b) Duplicate full capacity oil to water heat exchangers with two oil pumps—one working and one as standby;

c) Water flow indicator with alarm and trip contact;

d) Oil flow indicator with alarm and trip contact;

e) Surge diverters on the primary and secondary side of the furnace transformer; and

f) Separate tank for tap changer oil (in case of load tap changers, the tank of the diverter resistance) with separate gap pressure relay and level indicator.

4.6 Reactor — Depending upon the size of the furnace and electrical rating, a series reactor may be necessary to stabilize the arc and limit electrode short circuit current. This reactor may be built into the transformer or mounted separately. The reactor in either case should be provided with off load tappings to select a proper value depending upon system

fault level and quality of charge material. Generally, for furnace with transformer ratings above 8 000 kVA, series reactor may not be provided.

Remote operated shorting switch shall be provided when a separate reactor is offered.

IS : 2026 to be followed for design and testing of reactor as well as for necessories to be provided insofar as applicable till such time a standard on arc furnace transformer is adopted.

4.7 Furnace Circuit Breaker — The switchgear should be designed to withstand vigorous duty, that is, frequent operation (100 per day) both for breaking the magnetizing current of the transformer as well as clearing the fault and short-circuit conditions during melting operation.

The furnace circuit-breaker shall be oil, air blast or vacuum type.

In case the furnace circuit-breaker is not suitably rated to clear the supply fault level, it will have one second withstand capacity at least equal to the prospective symmetrical fault current of the system to which it is connected. This will be as per IS : 2516 as far as applicable.

For fixed type furnace circuit-breaker, properly interlocked off-load isolator shall be provided on the incomming side or isolating the breaker for maintenance purpose.

4.8 Furnace Electrical Control Arrangement — The furnace electrical control system should include control for various components, metering, interlocks, protective relays, annunciation and tripping system.

4.9 The arc furnace shall be suitable for adopting the following optional equipment with suitable modifications:

a) Water cooled panel for side walls,

b) Water cooled roof,

c) Fume extraction equipment,

d) Sponge iron feeding system, and

e) Oxy-fuel burner system (injection facilities).

5. SAFETY REQUIREMENTS

5.1 The furnace components should be designed to meet safety requirements specified in IS : 9080 (Part 1)- 1979* and IS : 9080 (Part 4)- 1981†.

*Safety requirements in electro-heat installations: Part 1 General requirements.

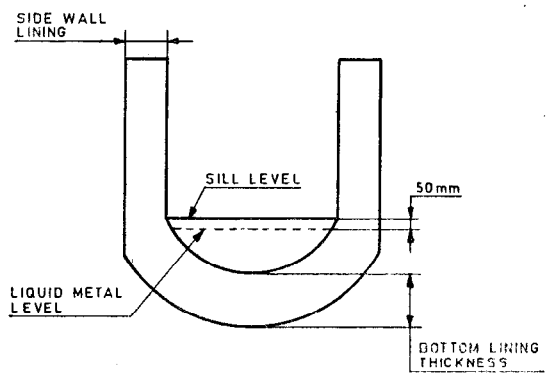
†Safety requirements in electro-heat installations: Part 4 Particular requirements for arc furnace installations.

TABLE 1 TYPICAL FURNACE DATA BASED ON INDIAN CONDITIONS

(*Clauses* 4.3 *and* 7.1)

Holding Capacity 50 mm Below Sill Level (M.T.)	Side Wall Lining Thickness Above Sill Level (mm)	Minimum Bottom Lining Thickness (mm)	Electrode Diameter (mm) Nominal	Maximum Secondary Voltage (V)	Electrode Current with Normal Grade 'A' Electrode (A)	Transformer Rating with Normal Grade 'A' Electrode (mVA)	Electrode Current with Grade 'B' Electrode (A)	Transformer Rating with Grade 'B' Electrode (mVA)
2/3	260	350	150	230	5 000	1·5/1·8	N.A.	—
5	260	400	200	250	7 500	2·5/3	N.A.	—
8	270	430	250	250	11 500	3·8/4·58	N.A.	—
12	305	500	300	270	16 800	6/7·2	22 000	8/9·6
16	305	500	350	275	22 000	7·5/9	30 000	10·5/12·6
20	305	500	350	300	23 000	9/10·8	30 000	11·66/14·0
25	355	525	400	315	29 000	12/14·4	38 000	15·6/18·75
35	355	550	450	330	35 000	15/18	46 000	18/21·6
50	355	600	500	385	40 000	18·75/22·5	50 000	23·3/28

NOTE 1 — The figures given in the above table are for guidance.
NOTE 2 — Grade 'A' electrode refers to normal grade.
NOTE 3 — Grade 'B' electrode refers to superior graphite grade with imported raw material.
NOTE 4 — Transformer of furnace sizes up to 12 tons shall be provided with 2 Const kVA tap.
For sizes 16 to 25 tons, 3 Const kVA taps shall be provided.
For sizes 35 tons and above, 4 Const kVA taps should be provided.
NOTE 5 — The minimum recommended secondary voltage shall be at least less than 50 percent of the highest secondary voltage.
NOTE 6 — The side wall lining thickness and bottom lining thickness should be read in conjunction with Fig. 1.
NOTE 7 — Magnesite basic lining material has been considered.
NOTE 8 — B grades electrodes are recommended with water cooled panel.
NOTE 9 — The charge having a density of 1 000 kg/m^3 can be fed to the furnace in maximum of two baskets.



NOTE — The shell bottom is shown dished. However it may have any other shape.

FIG. 1 ELECTRIC DIRECT ARC MELTING FURNACE

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6. TESTING PROCEDURE

6.1 The tests shall be carried out as per Indian Standard Methods of test for direct arc melting furnaces [ETDC 61 (2377)].

7. ARC FURNACE DATA

7.1 Typical arc furnace data based on Indian conditions is given in Table 1.

NOTE — Specific comments are invited from the users of arc furnaces for inclusion of details of approximate charge volume and any other detail in the table.

8. INFORMATION TO BE SUPPLIED BY THE MANUFACTURERS

8.1 The information to be supplied by the manufacturers at the time of submitting tenders shall be as given in Appendix A.

APPENDIX A

(*Clause* 8.1)

TECHNICAL DATA FOR DIRECT ARC MELTING FURNACE

A-1. MECHANICAL

a) Standard model reference type

b) Internal shell dia — mm

c) Internal shell height above sill level — mm

d) Internal shell height below sill level — mm

e) Furnace holding capacity in tonnes with.....mm bottom lining thickness and .....mm below sill level

(Liquid steel density 7 kg/dm^3)

f) Furnace charging volume — m^3

g) Sill height above operating floor level — mm

h) Size of slagging door (width × height)	mm
j) Max mum tilting angle for pouring	
k) Maximum tilting angle for slagging	
m) Clamp suitable for graphite electrode diameter	mm
n) Maximum allowable electrode circuit	A
p) Water pressure for cooling various parts of the installation	kg/cm²
q) Required quantity of cooling water for the cables, furnace and the transformer together at 4 kg/cm² considering the maximum inlet water temperature 35°C and cooling water temp, rise 20°C	l/s
r) System adopted for electrode control	
System adopted for tilting	
System adopted for door control	Please attach description and salient data of the system
System adopted for roof lifting/swinging device	
s) Requirements of compressed air	
— Flow rate	l/s
— Pressure	kg/cm²
— Duration/heat	min

A-2 ELECTRICAL

A-2.1 Transformer

a) Rating during melt down	kVA
b) Continuous voting	
c) Full kVA available on voltage tap	kVA
d) Constant current available on voltage tap	
e) Primary voltage	kV
f) Minimum secondary voltage	kV
g) Maximum secondary voltage	kV
h) Number of secondary tape	
j) Method of tap changing (remote controlled)	
k) Type of cooling	
m) Number of cooling circuits	
n) Secondary delta closed at	
p) Construction of secondary delta	
q) Percentage impedance	
r) Secondary connection details	

A-2.2 Reactor

a) Capacity	kVAR
b) Overload capacity	kVAR
c) Rated voltage	kV
d) Number of taps	
e) Method of reactor tap changing	
f) Whether mounted inside or separately from transformer	

A-2.3 HV Switchgear

a) Type of circuit breaker	
b) Rated voltage of circuit breaker	kV

c) Rated current of circuit breaker — A

d) Potential transformer rating — VA

e) Current transformer rating — VA

f) Rupturing capacity of circuit breaker — kA

g) Method of closing

h) Method of tripping

j) Frequency of maintenance required for circuit breaker

k) P.T.O

A-2.4 LV Current Transformer Rating Performance Data

a) Rated transformer capacity — VA

b) Maximum transformer capacity — VA

A-2.5 Guaranteed Data-Furnace Performance

a) Power consumption during melt-down and superheat to 1 520°C — kWh/t

b) Melt-down time for charge of — Tonnes — min

The performance guarantee procedure should be written as follows:

We guarantee the above power consumption and melt-down figures with a tolerance of ± 5 percent at a mettallic input of..... tonnes under the following conditions:

a) Two (2) baskets charging (including one back charging) per heat with roof not kept open for more than four (4) minutes per charging.

b) The melt-down period shall be the 'net' time for the melt-down including mechanical pushing of scrap and considering two basket charging. All interruptions, for example, switching off power while tap changing (applicable for off load tap changing system), recharging of scrap adjustment of electrodes, etc, are not included in the guaranteed melt-down time.

c) The melt-down period shall be considered terminated when the temperature of stove bath is approximately 20°C above liquids (that is, for example, 1 520 C for 0·5 percent carbon content in the melt). The melt-down time will be determined by using dip type immersion thermocouple dipped in the metal near the door area.

d) The performance guarantee demonstration will consist of maximum five (5) successive heats of which the average of the melt down times for three (3) successful heats shall be taken as demonstrating the performance guaranteed.

If within the first four (4) tests proof of guarantee performance cannot be given, additional reasonable periods shall be allowed, enabling the supplier to repeat the furnace performance. The furnace supplier shall be allowed to repair or readjust the plant.

e) The furnace refractory must be hot, that is, at least three (3) heats must have been produced immediately prior to the performance demonstration.

f) The supplier shall indicate the requirements of various operating supplies and services before conducting the performance guarantee test. Client will ensure availability of such materials and services during the performance guarantee test.

g) The furnace must be operated by the customers operating personnel having adequate experience in operating direct arc melting furnace under the direct supervision of suppliers personnel.

h) At the beginning of each heat during the performance demonstration, all installed electrodes must have the same working length between electrode tips.

j) The weight of the materials charged before melting must be established by weighing to an accuracy of the weighing system available for the purpose. Seller shall clearly specify use of oxygen (for assisted melting) during demonstration of melting energy and melting time guarantee.

k) The carbon content of the charge should be sufficient to give the opening carbon content of about 0·5 percent after melt down.

m) The time between tapping of one heat and starting the next heat (switching 'ON') shall not be more than 10 minutes.

n) The onload operating voltage should be .....kV with an admissible deviation of maximum −5 percent. If the voltage drops below this limit for more than a total of 5 percent of the melt-down time, energy consumption and net melt-down time shall be accordingly corrected as per the formula given below:

Melt-down energy variation } Formulae to be given by M/s GEC, Calcutta shall be incorporated in the draft standard.
Melt-down time variation }

p) While demonstrating the melt-down energy consumption and melt-down period, scrap charge blocking the door shall be pushed into the melt manually.

q) The consumption of electrical energy for melt-down shall be read from the kWh meter provided for the arc furnace installation. The kWh meter shall be connected to the high voltage side of the furnace transformer.

r) If for reasons beyond the control of the seller, the guarantee performance data cannot be demonstrated within 6 months after the sellers notification to the customer for the readiness of supply of the complete equipment after inspection by the customer, or two weeks after commissioning of the electric arc furnace whichever is earlier, the performance guarantee will be regarded as fulfilled. However, this time limit will not be applicable in case of retesting of performance guarantee as given above in item (d).

A-2.6 Other Information — Other information which shall be included with the tender is as follows:

a) Technical description of various mechanical, electrical equipments, interlocks and safety devices, controls, instrumentation and signalling devices, etc. The description should highlight the functional description, specific design features, materials of construction, etc.

b) Type of protective painting, etc.

c) Initial requirements of greases, lubricants, transformer oils and their specifications for individual units.

d) Required capacity of crane hooks for lifting and handling of split shell or removable shell type furnace with specification of hook and traverse.

A-2.7 Service Data (To be arranged by furnace user)

a) Power

i) HT power — kV — MVA fault level 3 phase 50 Hz AC

ii) LT power — Volts — MVA fault level 3 phase 4 wire 50 Hz AC

b) Cooling water

	Qty m^3/h	Pressure kg/cm^2
i) Normal flow for furnace welding transformers		
ii) Emergency flow for furnace only		

c) Compressed air